RESEARCH HIGHLIGHTS

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Technical Series 03-105

PENETRATION OF OUTDOOR PARTICLES INTO A RESIDENCE

Introduction

Outdoor respirable[1] and inhalable[2] fine particles (PM) are a significant factor which negatively affect health. Outdoor PM is known to penetrate into homes even when the doors and windows are closed. Due to the high portion of time spent indoors (90 per cent for most North Americans) the exposure of a person to outdoor-originating PM while indoors may be significant.

On a practical level, there are many fine particles of outdoor origin such as wood smoke, particulates from vehicles and industrial sources that should be excluded from the indoor environment.

Research Program

The objectives of this study were to determine how filtration and ventilation system operation can affect the indoor-outdoor relationship of fine particle concentrations in a home, as well as to determine the filtration effect of the house envelope on incoming ventilation or infiltrating air.

The study was limited to one, southern Ontario Canadian home with moderate airtightness. The house was operated with normal occupancy of two adults and with five distinct ventilation modes as follows:

1) Supply Only, No Filtration
2) Exhaust Only, No Filtration
3) Balanced, No Filtration
4) Balanced, with HEPA Intake Filter
5) Supply Only, with HEPA Intake Filter

Ventilation rates ranged between 0.71 and 1.20 air changes per hour and were selected to ensure that for the Supply Only arrangements, all of the incoming air passed though the ventilation system, and in the case of the Exhaust Only arrangement all of the incoming air passed though the building envelope.

Test Measurements

Continuous real-time measurement of indoor and outdoor particulate levels were made in five locations using an automated sampling rig developed by Bowser Technical Inc and coupled to a four-channel optical particle counter. Conversion of the count data to mass-based scales such as PM1, PM2.5 and PM10 were made based on earlier validation testing of the particle-counting rig. PM1 (particulate matter less than 1 μm) and PM10 data are reported in this study as there is less uncertainty associated with the conversion of the particle count data to these values.

Air temperature, air pressure, wind-speed and ventilation flows were also measured continuously. A total of 428 data-hours were used for data-analysis.

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[1] Particulate matter less than 2.5 μg, also called PM2.5

[2] Particualte matter less than 10 μg, also called PM10

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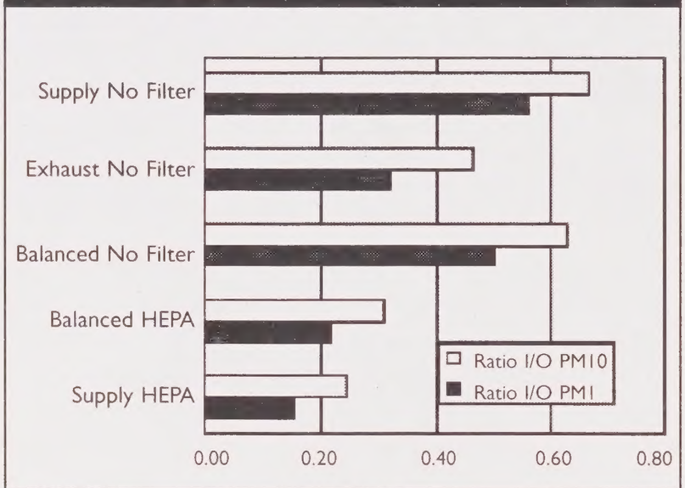
Findings

The non-filtered ventilation arrangements resulted in higher levels of indoor particles relative to outdoor levels. Filtered ventilation arrangements resulted in significantly lower indoor levels relative to outdoor levels. Exhaust Only ventilation arrangements (incoming air filtered by the house envelope) resulted in ratios in the mid-range between the filtered and un-filtered ventilation cases. The differences in indoor particle levels ratios are shown in Figure 1.

Figure 1: Average Indoor/Outdoor Particle Ratio



Comparison of the data with a mass-balance model showed that, for a fixed rate of indoor particle generation/re-suspension, there was poor correlation of measured and predicted particle levels for the filtered ventilation modes, but good correlation for the unfiltered ventilation modes. It was concluded that this occurs because the indoor particles in the filtered ventilation modes are dominated by indoor generation/re-suspension caused by the occupants which is quite variable. In the unfiltered cases however, the improved correlation of measured with predicted levels demonstrated that indoor levels are dominated by outdoor levels.

Figure 2 shows that for the Supply Only filtered case, the indoor particle levels are essentially independent of the outdoor levels showing small peaks in the morning and evening from occupant activity. Figure 3 shows that for the Supply Only with No Filtration case, the indoor particle levels are influenced predominantly by the outdoor particle levels and the influence of the occupants is relatively minor.

Figure 2: Sample data, Supply Only with HEPA Filter PM1 (μg/m³) vs time

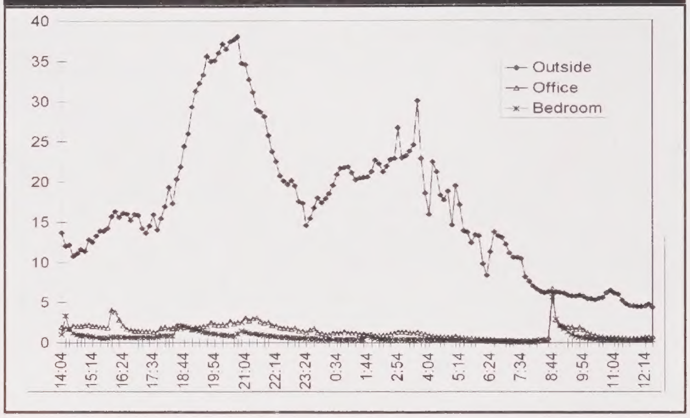
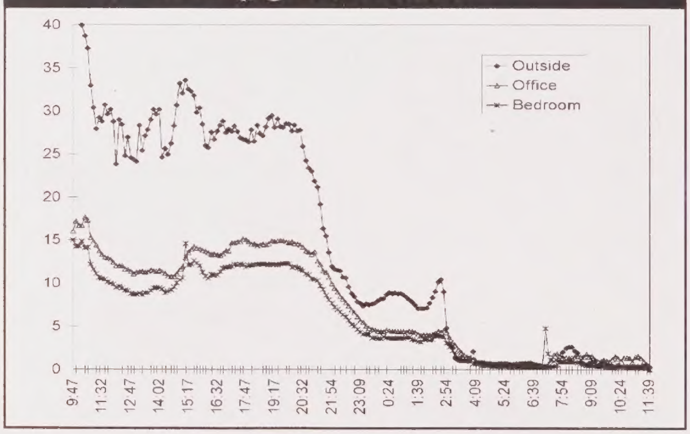


Figure 3: Sample data, Supply Only with No Filtration PM1 (μg/m³) vs time



Further analysis of the data using the mass-balance model predicted filtration factors (removal rate of incoming particles) for the building envelope of 43 per cent and 37 per cent for the PM1 and PM10 size ranges respectively. These results are shown in Tables 1 and 2.

Table 1

Set-Up	Filtration Factor PM1	Correlation (R^2)	Standard Error
Supply No Filter	0.06	0.99	44%
Exhaust No Filter	0.43	0.98	15%
Balanced No Filter	0.07	0.95	28%
Balanced HEPA	0.88	0.76	26%
Supply HEPA	0.99	0.59	8%

Table 2

Set-Up	Filtration Factor PM10	Correlation (R^2)	Standard Error
Supply No Filter	0.06	0.99	53%
Exhaust No Filter	0.37	0.97	13%
Balanced No Filter	0.04	0.73	138%
Balanced HEPA	0.81	0.45	106%
Supply HEPA	0.99	0.20	40%

In general, it was found that there are substantial benefits to filtering the incoming ventilation air. The benefits of filtering appear to be only slightly reduced for balanced ventilation systems when compared to supply-only ventilation systems. Ventilation air which enters via the building envelope appears to experience a significant degree of filtration.

Implications for the Housing Industry

Bringing unfiltered outdoor air directly into a home through an open, unfiltered intake allows outdoor particles to penetrate directly into the home. If the occupants desire some protection from outdoor contaminants this situation is to be avoided.

If outdoor air is introduced to the house via an intake duct to the central air handler or furnace, the filtration of outdoor air particles will only be as good as the filter in the air handler. If outdoor air is introduced by means of a central ventilator such as an HRV, outdoor fine particles will enter the home easily unless an effective filter is included in the system.

An exhaust-only type of system provides some protection from outdoor particles because it takes advantage of the natural filtering action of the building assemblies.

The best protection from outdoor particles is provided by a system which positively pressurizes the house while cleaning the incoming air with a high-efficiency filter. The main drawback of this type of system is the tendency to introduce moisture into the building envelope assemblies during the winter.

A balanced ventilation system (such as HRV) can provide a performance which approaches that of the filtered supply-only system, even for a house which is only moderately air-tight. This type of system does not have the problems which may arise from positive or negative pressurization and is adaptable to energy recovery.

These findings may prove to be useful for those persons with specific respiratory challenges due to outdoor sources.

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Housing Research at CMHC

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